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NEW RECOVERY ENERGY TURNSTILE ACHIEVED THROUGH RESEARCH AND INNOVATION ECO-DESIGN METHOD (EQFD)

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ABSTRACT

The present paper focuses on the recovery of energy from the unitary passage of people inside the turnstiles. Positioned at strategic points such as stadiums, buildings and fairs, the turnstiles are objects that interact with a large number of people, so we decided to take advantage of this peculiarity to get electricity immediately usable [1-3].

The issue of energy sustainability is increasingly discussed in terms of climate change that is undergoing our planet; hence an ever increasing awareness of avoiding energy losses in all phases of everyday life, even in those apparently unimportant. In our case, people do not have to change their habits or gestures during the turnstile approach, what changes is the concept of passing that becomes the protagonist and fundamental to reach our goal [4-5].

KEYWORDS: Energy Harvesting, Inflow, Unitary Transition & Rotation

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Original Article

INTRODUCTION

Each single action is made with an energy loss in the environment. Many projects have been made since the last decades in order to regain a little amount of energy from machines, vehicles or people movements. This process is called Energy Harvesting and is focused on renewable alternative energy sources. Energy is regained from reachable sources as radio and television broadcasts, electromagnetic emissions, mechanical motion, solar energy and thermal gradients.

The practical case that was authors' inspiration and starting point is Lybra, an intelligent retarder that exploits the deceleration of the cars during the braking phase (Figure 1). Strategically positioned in the points of greatest turnout, Lybra transforms the kinetic energy into renewable and immediately available electric energy going to form real modular and customizable "energy platforms" [6].

Figure 1: The Case of Lybra

There are also other examples of applications and experiments on roads or in any areas of traffic, but the goal remains the same, to recover energy.

METHODOLOGY

Authors used the method of Q.F.D. (Quality Function Deployment) to set the design according to the most anticipated requirements / features from a customer perspective. In this case, being a “green application”, it would be better define and use EQFD (Eco QFD) [7]. These requirements are evaluated numerically, in order to define an order of priority and importance.

The first step was to respond to the six questions: "Who? Where? When? Why? How? What?” in order to define our project scenario (Figure 2).

who	**car**	**train**	**pedestrian**	**bicycle**
where	High speed roads Slowdown Traffic Tunnel Roundabout	Slowdown Railway Tunnel	Croud Points of interest Events Sidewalk	Croud Bicycle lane
when	Going trough Braking	Going trough Braking	Walking trough	Going trough
why	Air movement Kinetic energy	Air movement Kinetic energy	Continuous turnout Discontinuous turnout	
how	Movement Pressure	Movement Pressure	Movement Pressure	Pressure
what	Piezoelectric Lybra Turbine Fan Kers Pressure platform	Turbine Kers Turbine	Piezoelectric Modular flooring Seats Turnstile	Piezoelectric

Figure 2: EQFD Six Questions

Thanks to this table, we have crossed the six questions with four possible interpreters (cars, trains, pedestrians and bicycles) going to define four possible scenarios to work on. The choice fell on people, as it turned out to be a very little investigated area and with several interesting ideas.

Once the interpreters of our project have been defined, we have started to work with real requisites and thanks to specific matrices we have defined those on which to focus our work. First, we have the “Relative importance matrix” (Figure 3).

		1	2	3	4	5	6	7	8	9	10	11	
1	Material resistance		0	0	2	1	0	0	0	0	2	2	7
2	Weather and mechanical restistance	2		2	2	1	1	2	1	2	2	2	17
3	Usability	2	0		2	2	0	1	0	0	2	2	11
4	Form	0	0	0		0	0	1	0	0	2	2	5
5	Maintanability	1	1	0	2		1	0	1	0	2	2	10
6	Unitary passage	2	1	2	2	1		1	1	2	2	1	15
7	Access authorization	2	0	1	1	2	1		1	2	2	2	14
8	Cost	2	1	2	2	1	1	1		0	0	1	11
9	Energy storing	2	0	2	2	2	0	0	2		2	2	14
10	Energy saving	0	0	0	0	0	0	0	2	0		1	3
11	Dimension and size	0	0	0	0	0	1	0	1	0	1		3

Figure 3: EQFD Relative Importance Matrix

Values range from 0 to 2, based on how much the horizontal requirement is more or less important than the vertical one. In our case, the most important ones were "atmospheric and mechanical resistance", "unitary passage", "passage authorization" and "energy accumulation".

The second matrix used is the "Cause-Effect" (Figure 4). In this case, the possible values are 0, 1, 3, 9 depending on how much the horizontal requirement is dependent on the vertical one. Corresponding to the largest total horizontally, the most dependent requirements are "ease of use", "shape", "unit passage" and "dimensions and dimensions".

On the other hand, the independent requirements are the "maintainability", "passage authorization", "energy accumulation" and "energy saving".

		1	2	3	4	5	6	7	8	9	10	11	
1	Material resistence		9	1	3	3	1	0	9	0	1	3	30
2	Weather and mechanical restistance	0		0	9	3	9	1	3	1	0	0	26
3	Usability	0	0		9	3	9	9	1	1	0	0	32
4	Form	0	3	9		9	9	1	3	0	0	9	43
5	Maintanability	0	0	0	3		0	0	1	0	1	3	8
6	Unitary passage	9	9	0	0	0		1	0	9	9	9	46
7	Access authorization	0	0	3	3	0	9		1	0	0	1	17
8	Cost	9	3	0	0	0	0	1		0	0	0	13
9	Energy storing	0	0	1	3	1	0	0	9		9	3	26
10	Energy saving	0	0	0	0	0	0	0	9	0		0	9
11	Dimension and size	9	9	9	9	3	9	1	9	9	0		67
		27	33	23	39	22	46	14	45	20	20	28	

Figure 4: EQFD Cause-Effect Matrix

The final step was to analyze our competitors through a study of the proposed models. Through a tool called Benchmarking, we were able to draw up a list of the features proposed by each model and understand thanks to the "innovation column" what the ideal product should look like.

Once the "innovation column" was defined, we used the "Top Flop analysis" (Figure 5) to understand how many features to innovate to make our project innovative.

Company	Automatic system	El-go team	Gotschlich	Ollagnir sca	Gastop	Ideal product
Model	TRS 370	STF 01	Ecco 120 bfb	Tm sp	BR3 1 3	
Movement	Central rotation axe	Sided rotation axes	Central rotation axe	Central rotation axe	Central rotation axe	Central rotation axe
Division angle degree	90	//	120	180	120	120
Material	Galvanized steel	Galvanized steel	Steel	Stainless steel	Stainless steel	Stainless steel
Access authorization	No	Yes	No	No	Yes	Yes
Configuration	Free or monitored	Monitored	Free	Free	Monitored	Monitored
Unitary passage	Yes	Yes	Yes	No	Yes	Yes
Anti-intrusion structure	Yes	Yes	Yes	No	Yes	Yes
Security barrier	Opposizione dietro	//	Rounded	Opposizione al centro	Rounded	Rounded
Direction (entrance/exit)	One way	One way	Both ways	One or both ways	One or both ways	One way
Use	Indoor and outdoor	Indoor	Outdoor	Indoor and outdoor	Outdoor	Outdoor
Energy consumption	Low	High	Low	Low	Low	Low
Affordance	High	Low	Medium	High	Medium	High
Extra	Light signal		Disabled access			Energy harvesting Disabled access Light signal
Top	7	5	8	6	11	
Flop	2	5	3	6	0	
Δ	5	0	5	0	11	

Figure 5: Top Flop Analysis

The characteristics to be proposed in our project were found to be 11 (delta = 11), with the mission to add at least one to make the product innovative. The possibility of recovering energy becomes the added value we offer.

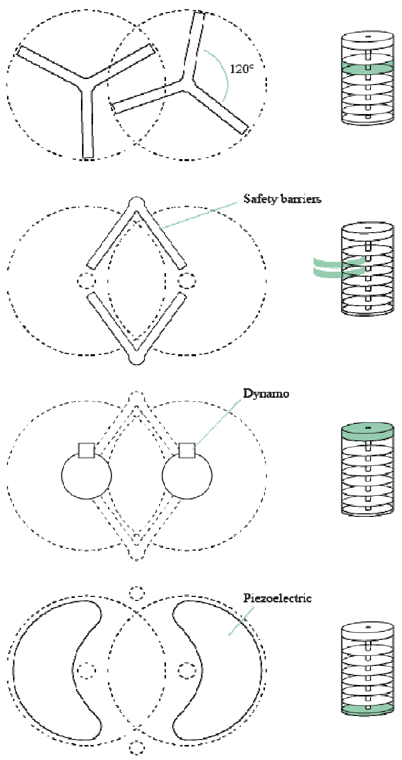

Figure 6: Project Development and Architecture

CASE STUDY

The turnstile is an obligatory place of passage that conveys people by allowing access to the structure. What interested authors was the mechanism of passage, the action itself of the movement, and how to exploit these repetitive actions performed in series by thousands of people.

Targets

To obtain and store energy by exploiting the obligatory passages of people at the entrance to high-traffic places.

Project Setting

First of all, authors compiled a list of components that go to make up a full height turnstile: two entrances, safety barrier between the two inputs, code reader, security panel, external body.

PRODUCT DEVELOPMENT

Authors selected the two methods to recover energy respectively, through the dynamos placed in the upper part of the structure or through a plate formed by piezoelectric crystals placed, instead, in the lower part and walkable [8-12].

The second solution, once assessed in terms of costs and actual energy benefits, was discarded because it was not very convenient.

In the development of architecture, authors choose to use a rotating shaft with a radius of 120 degrees; in this way, each person is given more pressure to pass maximizing the recoverable energy.

The safety barriers separating the two rotating shafts and then the two entrances are specular to facilitate installation and production (Figure 6).

Authors started by developing three styles, in order a Futuristic style, a Natural and a Stone (Figure 7). Obviously, each proposal presented the winning characteristics and the weak points that concerned both the industrialization and the emotional impact with people; what we did was therefore, to merge and mediate the winning features of each proposal to create something new. The first shell, the Futuristic, is realizable with one single piece of bended material that covers all the parts of the turnstile. This concept has many issues about costs and production. The second shell, the Natural, is very easy to produce and it feels like an open and light structure. Most of the parts are the same, only the external structures are different from the others. The third shell, the Stone, is easy to produce but it gives a tough impression. The shape of the Stone allows placing one turnstile beside another, facilitating the wiring operations.

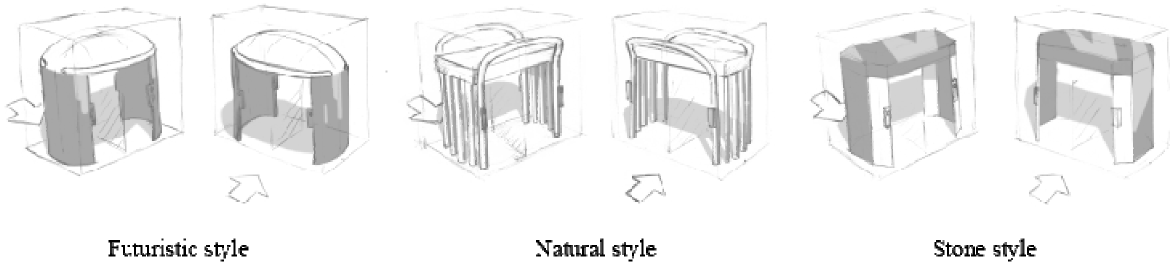

Figure 7: Sketching Proposals

MATERIALS AND COSTS

The materials used are 2mm thick sheet steel for the walls and 1.5mm for the upper body. To form the sheet, we use bending, cutting and welding. For pipes, which have a diameter of 60mm, 50mm, we use cutting and welding. Finally, for the plexi glass, 5mm thick, we use thermoforming.

The drawing shows the product, resulting from the merging of the styles and the entry and exit direction (Figure 8).

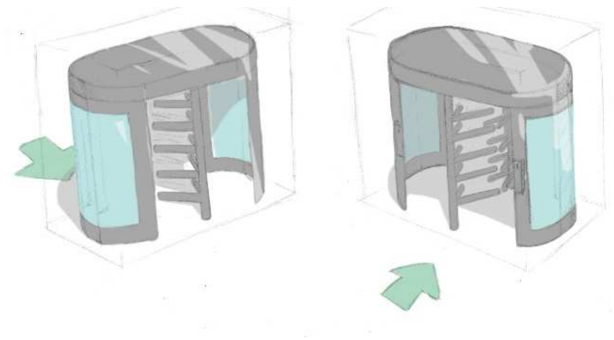

Figure 8: Study of Materials

The rendering was the next step; here, we have realistically rendered the surfaces by also representing the ticket reader screen in action. The screen appears green with a tic if the passage is included, red with an x if instead the person cannot pass (Figure 9). The dimensions of the turnstile are designed in order to allow a double access. It is 2390 cm wight, 2452 cm height and 1570 depth (Figure 10) [13-17]

Figure 9: First Rendering of the Front View

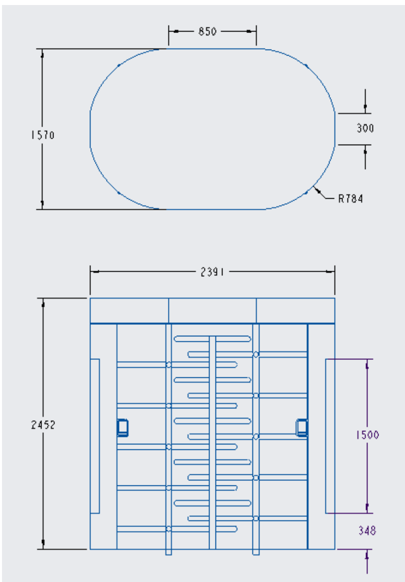

Figure 10: 2D Views and Relative Dimensions

COST ANALYSIS

Authors estimated the costs of product development based on a 16 month design, assuming the number of resources allocated per activity, duration and costs (Figure11).

	H/month	n° month	n° people	€/h	Total
R&D cost	160	3	1	40	19200
Architecture & style	160	4	2	40	51200
Cad	160	3	3	40	57600
Rendering & prototyping	160	2	2	40	25600
Test	160	2	5	25	40000
Tuning	160	1	1+1	40+25	10400
Redesign	160	1	1	40	6400
					210400 €

Figure 11: R&D Costs Estimated

The total obtained was then subdivided into a hypothetical batch of 1000 products. The unit cost of production is obtained by adding the costs of materials, the machine costs, and the amount of the R & D costs (*Figure 12*).

Elettric material	+	Structural material	−	Machine power	+	R&D	=	Total
3938 €	+	4162 €	−	1,52 €	+	260 €	=	8361,52 €

Figure 12: Sum of the Components of R&D Costs

RESULTS

SWOT Analysis

SWOT is a technique used to photograph the situation of the project today, it highlight strengths, weaknesses, opportunities and threats of it (Figure 13).

Once the strengths and weaknesses have been defined and clarified, authors focused on the threats and opportunities associated with the turnstile. The main threat is that the project cannot have significant potential in the short term; this because of today's technological limitations. It is hoped that in the near future, the energy harvesting can increase significantly thanks to the general technological development.

STRENGHT	WEAKNESS
- Energy harvesting	- Costs
- Doesn't change habits	- Low energy saving
OPPORTUNITY	**THREAT**
- Technology innovation	- Not so huge potential in the nearer future
- Everyday life	

Figure 13: SWOT Analysis

Energy Harvesting

For example, authors can assume the application of the turnstile in the Dall'AraBologna stadium. We can assume a maximum attendance of 35,000 people. With this frequencies, each game or event inside the stadium could generate 3 kWh (kilowatt hours), thanks to the technological tools available today.

This energy can be used in different ways:

- We can illuminate a single home or an apartment for one hour;
- We can illuminate a streetlight lamp up to 20 h;
- We can self-power the turnstile, that becomes self-sufficient, plus a small battery for its ignition.

CONCLUSIONS

The project responds to the challenge of energy harvesting by placing people and their interactions with objects at the center of the design. Today, the turnstile is our answer for a future in which, energy will be harvested from human activities. In the next future, we hope that energy harvesting will have mass attention, and many people will start to care about the future of the Earth. By sensitizing people to energy harvesting, we can imagine a future, in which, many of our daily actions can obtain a small amount of energy. These actions can take place at home or in common places, throwing our thinking towards the smart city.

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